Assessing Fatigability in Mobility-Intact Older Adults

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OBJECTIVES: To evaluate the criterion validity of two measures of fatigability, defined as performance deterioration or perceived effort to perform a standardized task.

DESIGN: Cross-sectional analysis of data from the Baltimore Longitudinal Study of Aging (BLSA).

SETTING: National Institute on Aging, Intramural Research Program, Clinical Research Unit, Baltimore, Maryland.

PARTICIPANTS: Six hundred five men (53.7%) and women aged 65 to 97 participating in the BLSA and eligible for endurance walk testing without a walking aid.

MEASUREMENTS: Fatigability was assessed using completion status and lap times from a 400-m walk performed "as quickly as possible" and perceived exertion rating using the Borg scale (range 6–20) after 5 minutes of treadmill walking at 1.5 miles per hour (0.67 m/s). Criterion measures included self-report of tiredness, level of weakness and energy in past month, and walking ability and objective measures of usual and fast gait speed, time to complete 10 chair stands, and grip strength. Covariates included age, race, sex, obesity, smoking status, and walking activity.

RESULTS: Of mobility-intact older persons, 23% exhibited performance deterioration (slowed or stopped) during the 400-m walk, and one-third reported more than very light exertion after a 5-minute slow walk. Slowing was strongly associated with self-reported fatigue and walking ability but weakly associated with performance-based mobility measures. High perceived exertion was associated with tiredness, weakness, and reported and observed mobility deficits.

CONCLUSION: Slowing down may have low sensitivity for identifying fatigability in older persons, but ascertaining perceived exertion during a defined workload shows promise. In seemingly healthy, motivated individuals, fatigue and fatigability were common and may affect socially meaningful mobility behaviors. Assessment of fatigability in well-elderly examinations may help identify threats to independent functioning earlier in the decline process.
J Am Geriatr Soc 62:347–351, 2014.

Key words: fatigue; fatigability; performance measures; validation; mobility

Fatigue is a common complaint in older persons, with increasing fatigue considered to underlie the activity reduction[1,2] and functional decline frequently observed in older age.[3,4] Prevalence estimates range widely, and although some studies have found that fatigue increases with age,[4] others have found no strong age relationship.[5] Although fatigue is associated with most end-stage diseases and is an independent risk factor for mortality,[4,6] little empirical evaluation exists of the relationship between fatigue and functional status of older adults, with a few notable exceptions.[7–9]

The paucity of research and inconsistent findings stem from the lack of a uniform definition and approach to measuring fatigue. Assessments vary from a few items extracted from depression screening instruments[10] to disease-specific questionnaires[11] and task-specific scales.[7] How individuals typically respond to symptoms (by reducing activity to remain below their fatigue threshold) can bias ascertainment of general fatigue.[3] Thus, reported fatigue levels may be similar even when the intensity of activity that brings on fatigue differs substantially.

The fifth Bedside-to-Bench conference, "Idiopathic Fatigue and Aging," identified development of fatigue measurement tools as instrumental to further understanding of factors that contribute to fatigue and fatigability, a newly defined construct, and the role that fatigability plays in disablement.[12] In this context, fatigue refers to a perceived lack of physical energy and weariness, and fatigability reflects perceived inability to continue an activity at the same intensity with resultant performance deterioration and the degree of fatigue experienced in relation to performing a standardized activity.[1,3]

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DOI: 10.1111/jgs.12638

0002-8614/14/$15.00

This study evaluated the criterion-related validity of two newly developed performance-based fatigability measures. The first targets performance deterioration assessed as marked slowing or inability to complete a fast-pace 400-m walk; the second targets degree of fatigue experienced or, analogously, perceived exertion during a standardized activity (walking 1.5 miles per hour (mph) (0.67 m/s) on a treadmill for 5 minutes). To test concurrent validity, the association between each fatigability measure and reported fatigue symptoms such as tiredness, weakness, and low energy was examined. For predictive validity, the association between reported walking ability and measured performance, including usual and fast gait speed, time to complete 10 chair stands, and grip strength, was examined.

METHODS

Participants

The study population consisted of 605 men (53.7%) and women aged 65 to 97 participating in the Baltimore Longitudinal Study of Aging (BLSA), a continuous enrollment cohort study of normative aging. Eligibility at enrollment is restricted to persons free of cognitive impairment, functional limitations, chronic diseases, and cancer within the past 10 years. Participants receive regularly scheduled comprehensive health, cognitive, and functional evaluations over a 3-day visit to the BLSA clinical facility. Visits occur every 4 years for persons younger than 60, every 2 years for persons aged 60 to 79, and annually for persons aged 80 and older. Participants in the current study were seen between March 2007 and May 2011.

The performance deterioration sample consists of 588 BLSA participants eligible for the Long-Distance Corridor Walk (LDCW; described below) who are not dependent on a walking aid. The perceived exertion sample consists of 470 BLSA participants seen after July 2007, when the slow treadmill walk was implemented, and constitutes a subsample of the performance deterioration group. Seventeen persons in the perceived exertion sample were not administered the LDCW for health-related exclusion (n = 7) or clinic administrative (e.g., shortened visit, staffing limitations) reasons that precluded testing (n = 10).

Fatigability Measures

Performance Deterioration

Performance deterioration was assessed using the LDCW, a two-stage, self-paced endurance walk test performed over a 20-m course. Stage one consists of a 2.5-minute walk in which participants are instructed to walk at their usual pace; stage two follows immediately and consists of a 400-m walk done "as quickly as possible at a pace that can be maintained."[13,14] The BLSA version collects individual lap times for ten 40-m laps during the 400-m component. Persons eligible for the LDCW who were unable to begin the 400-m walk after completing the first stage, were unable to complete 400 m without stopping, or exhibited marked slowing over the 10 laps were considered to exhibit performance deterioration. Marked slowing was defined as an increase in lap time between the second and ninth laps of at least 6.5%. The second and ninth laps were used to minimize the effect of a faster-than-average starting and ending pace in anticipation of the finish. The value of 6.5% showed the best discrimination between persons reporting low and high energy level in the past month (see below).

Perceived Exertion. Immediately after a slow-paced 5-minute walk (1.5 mph; 0.67 m/s) performed on a treadmill at 0% grade, participants were asked to rate their perceived exertion using the Borg rating of perceived exertion (RPE) scale (range 6–20; 6 = no exertion at all, 9 = very light, 11 = light, 13 = somewhat hard, 20 = maximal exertion).[15] The speed of 0.67 m/s was selected because it distinguishes frail from nonfrail individuals[16] and is sufficiently low demand to minimize participant exclusion. All persons who were not dependent on walking aids were included. Given the low-demand nature of the task, high fatigability was defined as a RPE of 10 or greater, which corresponds to perceived exertion just exceeding very light. For comparison, ratings of 11 or greater are considered in the training range.[17]

Fatigue Measures

Measures of fatigue were examiner-administered, reference the past month, and cover perceived tiredness, weakness, and energy level. All measures were dichotomized with cutpoints selected to identify between 20% and 30% as having each symptom, with the exception of tiredness, for which, because of limited dispersion, 42.5% were identified as having tiredness. Persons reporting they "felt unusually tired during the day" all, most, or some (vs none) of the time were considered to exhibit tiredness. Participants rating their weakness level as 3 or greater on an 11-point scale (0 = not weak at all, 10 = very weak) were coded as reporting weakness. Those rating their usual energy level as 6 or lower on an 11-point scale (0 = no energy at all, 10 = the most energy ever had) were considered to have low energy. A second energy item comes from the Medical Outcomes Study 12-item Short Form Survey,[18] in which persons reporting that they had a lot of energy, some, a little, or none (vs all, most, or a good bit) of the time were treated as expressing low energy.

Walking Ability and Physical Performance Measures

Reported walking ability was determined from responses to a set of questions beginning with, "Because of a health or physical problem, do you have any difficulty walking a quarter of a mile, that is about 2 or 3 blocks, without stopping?" Those reporting difficulty were asked whether they had a little, some, or a lot of difficulty or were unable to walk. Persons expressing no difficulty were asked how easy it is to walk one-quarter of a mile (very, somewhat, or not so easy) followed by whether they have any difficulty walking 1 mile and the ease of walking 1 mile if no difficulty was reported.[19] Responses were combined to create a walking ability index ranging from 0 to 9 (0 = unable to walk one-quarter of a mile, 9 = walking 1 mile is very easy).[20] Performance-based evaluations included usual and rapid gait speed assessed over a 6-m course, with the fastest of two trials used for analysis;

10 repeated chair-stands, with stands per second the unit of analysis; and grip strength, using the highest value of up to three trials on each side.

Covariates

Covariates encompass sociodemographic factors including age, sex, and self-identified black or nonblack race and behavioral factors known to affect functional performance, including smoking history (dichotomized as current or recent smoker (smoked regularly within the past 10 years) vs never or former smoker (stopped smoking for at least 10 years)), obesity (defined as a body mass index of $\geq$30.0 kg/m^2 derived from measured weight and height), and recent walking activity.

Statistical Analyses

For the primary analyses, the odds of reporting each fatigue symptom according to both measures of fatigability were determined from logistic regression analyses, controlling for age, sex, race, smoking, obesity, and recent walking activity. Reported walking ability and the performance measures were examined as continuous variables, with adjusted mean values compared according to fatigability status using least square means controlling for age, sex, race, smoking, obesity, recent walking activity, and height for grip strength only. Perceived exertion after the slow treadmill walk was also examined as a continuous measure using logistic regression to examine likelihood of fatigue symptoms associated with a unit change and linear regression to evaluate the associations with reported and observed functional performance. Analyses were conducted using SAS version 9.1 (SAS Institute, Inc., Cary, NC).

RESULTS

Population characteristics for the performance deterioration and perceived exertion samples are presented in Table 1. Persons exhibiting fatigability on either measure were generally older, more likely to be female, and less likely to have done any brisk walking in the past 2 weeks.

Performance Deterioration

Of the 588 participants in the performance deterioration sample, 134 (22.8%) met criteria for marked slowing; 10 of these did not continue on to the 400-m walk after the 2.5- minute usual-pace walk, 31 stopped the 400-m walk before completion, and 93 slowed between the second and ninth laps at least 6.5%. Those exhibiting performance deterioration had higher rates of fatigue symptoms, including tiredness, weakness, and low energy in the past month (Table 2) and poorer reported walking ability (Table 3), independent of age, race, sex, obesity, smoking history, and walking activity. These relationships held when persons who stopped were excluded from the analyses (data not shown). Differences in physical performance were less striking, with only usual gait and chair stand speed achieving statistical significance (Table 3). In analyses excluding the 41 persons who stopped, no differences in any physical performance test emerged (data not shown).

Perceived Exertion

Of the 470 participants in the perceived exertion sample, 149 (31.7%) had a Borg RPE of 10 or greater after a 5-minute walk at 1.5 mph (0.67 m/s) on a treadmill at 0% grade. Overall, Borg scores ranged from 6 to 18 (median 9). Persons reporting a RPE of 10 or greater were 60% to 100% more likely to report fatigue symptoms than those with ratings below 10 (Table 2). They also reported lower average walking ability and demonstrated poorer usual- and fast-pace walking and repeated chair-stand and grip strength performance (Table 3; $P < .001$ for all).

Using Borg RPE as a continuous measure, each additional point was associated with 15% greater likelihood of reporting each fatigue symptom (all $P < .005$, adjusted for age, sex, race, obesity, smoking history, and walking activity). There was also a strong relationship with the functional outcomes, with each additional point associated with 0.19 fewer points on the walking ability index, 0.021-m/s slower usual-paced gait speed, 0.028 m/s slower fast-paced gait speed, 0.014 fewer chair stands per second

Table 1. Participant Characteristics

Characteristic	Performance Deterioration Sample		Perceived Exertion Sample	
	Slowed, n = 134[a]	Maintained, n = 454	RPE $\geq$ 10, n = 149[b]	RPE < 10, n = 321
Age, mean $\pm$ SD	77.9 $\pm$ 8.2[c]	74.7 $\pm$ 7.1	77.5 $\pm$ 7.4[c]	73.9 $\pm$ 6.6
Female, n (%)	85 (63.4)[c]	188 (41.4)	80 (53.7)[c]	135 (42.1)
Black, n (%)	35 (26.1)	97 (21.4)	41 (27.5)	68 (21.2)
Body mass index $\geq$ 30.0 kg/m^2, n (%)	40 (29.8)	100 (22.0)	43 (28.9)	70 (21.8)
Smoker, n (%)[d]	5 (3.7)	13 (2.9)	4 (2.7)	8 (2.5)
Brisk walker, n (%)[e]	22 (16.4)[c]	142 (31.3)	28 (18.8)[c]	115 (35.8)

[a]Unable to attempt or complete a 400-m walk "as quickly as possible" or increased lap time between laps 2 and 9 at least 6.5%.
[b]Rating on Borg scale from 6 to 20 after 5 minutes of walking on a treadmill at 1.5 miles per hour (0.67 m/s).
[c]$P < .05$.
[d]Regular smoker currently or within the past 10 years.
[e]Reported having walked at a brisk pace within the past 2 weeks.
RPE = Rating of Perceived Exertion.

Table 2. Percent Reporting Fatigue Symptoms and Odds of Fatigue by Fatigability Status

	Performance Deterioration Sample			Perceived Exertion Sample		
Fatigue Symptom	Slowed, n = 134	Maintained, n = 454	OR (95% CI)[a]	RPE ≥ 10, n = 149	RPE < 10, n = 321	OR (95% CI)[a]
Tiredness[b]	57.3	37.6	1.69 (1.11–2.58)	56.1	34.1	1.85 (1.21–2.82)
Weakness[c]	38.2	18.1	2.17 (1.37–3.44)	33.1	15.0	2.08 (1.27–3.41)
Low energy[d]	46.2	21.5	2.59 (1.66–4.05)	34.0	20.0	1.63 (1.02–2.61)
SF-12 low energy[e]	38.2	15.4	3.03 (1.90–4.84)	25.8	16.1	1.62 (0.97–2.70)

[a]Adjusted for age, sex, race, walking activity, obesity, and smoking history.
[b]Reported feeling unusually tired during the day some to all of the time in past month.
[c]Reported a weakness level ≥3 in past month (0 = not weak at all, 10 = very weak).
[d]Reported a usual energy level ≤6 in past month (0 = no energy at all, 10 = most energy ever had).
[e]Reported having a lot of energy no more than some of the time in the past 4 weeks from the Medical Outcomes Study 12-item Short-Form Survey (SF-12).
OR = Odds Ratio; RPE = Rating of Perceived Exertion; CI = Confidence Interval.

Table 3. Mean Physical Functional Ability According to Fatigability Status

	Performance Deterioration			Perceived Exertion		
Functional Ability	Slowed, n = 134	Maintained, n = 454	*P*-Value[a]	RPE ≥ 10, n = 149	RPE < 10, n = 321	*P*-Value[a]
Walking ability score[b]	6.61	7.95	<.001	7.26	8.05	<.001
Usual gait speed, m/s[c]	1.05	1.10	.048	1.03	1.13	<.001
Rapid gait speed, m/s[c]	1.58	1.64	.09	1.55	1.69	<.001
10 chair stands, stands/s[d]	0.38	0.42	.02	0.36	0.43	<.001
Grip strength, kg[e]	31.7	31.8	.80	30.7	32.9	<.001

[a]Adjusted for age, sex, race, walking activity, obesity, and smoking history.
[b]Reported walking ability index derived from a series of self-report questions can range from 0 to 9 (see text) (0 = unable to walk one-quarter of a mile, 9 = very easy to walk 1 mile).
[c]Fastest of two trials over 6 m.
[d]Persons unable to complete 10 stands were assigned a value of 0.
[e]Highest value out of a maximum of three trials with each hand, adjusted for height.
RPE = Rating of Perceived Exertion.

and 0.46-kg less grip strength (all $P < .001$, adjusted for age, sex, race, obesity, smoking history, walking activity, and height for grip strength only).

DISCUSSION

In a mobility-intact population of older adults aged 65 and older, two fatigability measures (performance deterioration during a self-paced endurance walk test and perceived exertion after a slow treadmill walk) identified 23% and 32%, respectively, as having high fatigability. Performance deterioration and perceived exertion demonstrated good concurrent validity in showing consistently strong associations with each fatigue symptom. As for predictive validity, performance deterioration had a robust relationship with reported walking ability but weak associations with the physical performance measures that were driven largely by inability to continue walking because slowing alone was not predictive. In contrast, there was a robust association between perceived exertion and reported and observed function whether RPE was used as a threshold or continuous measure.

Performance on the LDCW and the 400-m walk component in particular has a well-established prognostic relationship with mortality and mobility limitation,[21,22] and several studies of aging have included a version of this well-tolerated assessment of exercise tolerance.[13] This study found that taking lap splits was useful for identifying persons with high fatigability primarily manifest in a propensity to report global fatigue symptoms and poor endurance-related walking ability. Even though a 6.5% increase in lap time best discriminated between those reporting low and high energy levels, persons who slowed down even 5% consistently had a higher prevalence of fatigue symptoms, especially low energy and tiredness ($P < .01$ for both). Additionally, although persons who slowed down tended to need more time to walk 400 m overall, the difference averaged just 12 seconds and was largely accounted for by age, sex, and race. Thus, slowing down is distinct from overall slower walking pace.

Perceived exertion during a low-demand activity discriminated between persons reporting fatigue symptoms and those with poorer functional ability along the full range of the measure and when used as a categorical classification. The primary limitation concerns use of a treadmill, which may render this specific approach impractical for some research centers and clinics. Nevertheless, the discovery that reported exertion after a low-demand

workload identifies persons with a low fatigue threshold, suggests that inquiring about perceived exertion after other standardizable activities warrants further consideration. For example, a previous study[23] found that tiredness level after completing a 10-minute corridor walk at a self-selected pace highly correlated with gait speed, physical activity, and general fatigue.

The primary study limitation was use of a sample of generally motivated, compliant individuals with no overt mobility limitations. Whether testing for fatigability in more-debilitated individuals would provide meaningful information or whether the majority of such individuals could even undergo or complete testing remains to be demonstrated. The previous study[23] in an older, less-robust sample found that 10 of 43 participants were unable to complete a 10-minute walk. In the current study, of the 30 persons unable to complete the full LDCW who were seen after implementation of the treadmill test, only 15 participated in the slow treadmill walk. These observations indicate that fatigability testing may be most suitable as an early marker of diminished capacity in otherwise well-functioning individuals. To fully evaluate the potential research and clinical utility of these fatigability measures will require longitudinal investigations of their usefulness in predicting relevant health outcomes.

Both assessments evaluated represent near-literal interpretations of the fatigability definitions offered previously.[5] The finding of somewhat different associations between these fatigability constructs as operationalized in this study raise the possibility that performance deterioration and perceived exertion after a standardized activity may capture different dimensions of fatigability, with performance deterioration identifying more global fatigue symptoms, whereas high perceived exertion may identify suboptimal performance capacity. Examining these measures together in the 453 participants with both assessments, 18.5% had performance deterioration, and 30.9% had high perceived exertion, yet only 8.8% met both fatigability criteria.

In summary, because early identification of impending limitation may facilitate more-effective treatment, evaluation of fatigability in apparently well-functioning older adults may provide an opportunity to improve health outcomes. As noted previously, the LDCW in its original form is a valuable prognostic indicator;[21,22] including lap split times is a minor modification that yields an assessment of fatigability. Ascertaining perceived exertion using the Borg scale after a 5-minute slow treadmill walk appears to provide a new meaningful, valid approach to assessing fatigability. Future studies must evaluate the degree to which these measures of fatigability predict future outcomes and functional decline, in particular.

ACKNOWLEDGMENTS

Findings were previously presented in preliminary form at the Gerontological Society of America Annual Meeting, Boston, Massachusetts, November 18–20, 2011.

Conflict of Interest: None.

Funding received from the Intramural Research Program, National Institute on Aging.

Author Contributions: Simonsick: study concept and design, analysis and interpretation of data, preparation of manuscript. Schrack, Glynn: interpretation of data, critical review of manuscript. Ferrucci: acquisition of participants and data, interpretation of data, critical review of manuscript.

Sponsor's Role: None.

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